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STABILITY OF FREQUENCY-WAVENUMBER  
NOISE SPECTRA AT UBO

8 September 1967

Prepared For

AIR FORCE TECHNICAL APPLICATIONS CENTER  
Washington, D. C.

By

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TELEDYNE, INC.

Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY  
Nuclear Test Detection Office  
ARPA Order No. 624

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STABILITY OF FREQUENCY-WAVENUMBER  
NOISE SPECTRA AT UBO

SEISMIC DATA LABORATORY REPORT NO. 197

AFTAC Project No.:	VELA T/6702
Project Title:	Seismic Data Laboratory
ARPA Order No.:	624
ARPA Program Code No.:	5810
Name of Contractor:	TELEDYNE, INC.
Contract No.:	F 33657-67-C-1313
Date of Contract:	2 March 1967
Amount of Contract:	\$ 1,736,617
Contract Expiration Date:	1 March 1968
Project Manager:	William C. Dean (703) 836-7644

P. O. Box 334, Alexandria, Virginia

AVAILABILITY

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This research was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, under Project VELA-UNIFORM and accomplished under the technical direction of the Air Force Technical Applications Center under Contract F 33657-67-C-1313.

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## ABSTRACT

Seven four-minute samples of the ambient noise were subjected to frequency-wavenumber (F-K) spectral analysis in order to observe the range and character of variations in the F-K power spectrum. The observations are derived from the same normal population. The apparent variation in the underlying noise statistics or processes do not suggest gradual diurnal variations in the noise power, but large and apparently random inter-day fluctuations.

## PROCEDURE

The SDL wavenumber-frequency analysis program VFKSPTRM due to McCowan and Jih was used to analyze seven four-minute samples of ambient noise recorded at the UBO vertical array on 14 April 1967, starting at 3/20/00.00, 4/42/00.0, 6/20/00.0, 9/00/00.0, 11/20/00.0, 14/00/00.0, and 15/15/00.0. Spectral peaks were observed at nearly infinite vertical velocity at 0.20 cps, 0.80 cps, 1.50 cps, and 2.00 cps. The variability of power observed at these frequency was subjected to Bartlett's test for homogeneity of variance (Kullback, 1959). For better accuracy the high frequency peaks were observed after bandpass filtering in order to prevent leakage through the spectral window due to the large .20 cps peak.

## TIME VARIATION OF THE SPECTRAL PEAK

Table 1 lists relative values of the spectral power observed at different times during the day at the specified frequency of F-K peaks observed in the noise. The vertical wave number of the peaks is nearly zero in all cases.

The .2 cps noise power was taken from the F-K spectral plots on Figures 1 to 7 with all observations normalized to the mean at .2 cps. The strip at the bottom of the Figures show the array response. The other observations were taken from the power spectral plots of band passed (.3 to 3 cps) data on Figures 8 to 14.

## MEAN, RANGE, AND STABILITY OF PEAK POWER AT EACH FREQUENCY

The arithmetic mean value observed for the spectral peaks in the noise is taken from Table 1, as is the range between the lowest and highest observation in the time interval between 3/20/00.0 and 15/19/00.0. The parameter t is measured for testing the hypothesis that the observed variability of variances is due to sampling and that the underlying

variance of the noise field is time invariant

$$T = 2(BT) (B'X) \sum_{i=1}^7 \log S_i^2 / S_i^2 S^2 = \frac{1}{7} \sum_{i=1}^7 S_i^2$$

where B is bandwidth of frequency analysis

T is time-length of sample

X is length of the vertical array

B' is bandwidth of wave number analysis.

There is no spatial smoothing in the program, so  $B'X \approx 1$ . This can be verified from the array response (using 3 km. for the length of the array). The smoothing of power in time results in  $B \approx .05$  cps and the time-length of the sample is 204 sec. The results of the t test are shown on Table 2. For acceptance of the hypothesis of homogeneity of variance t should be less than 12.63 in Fisher's  $B^2$  distribution.

## RESULTS

The probability of error in rejecting the hypothesis that the .2 cps noise is stationary is considerably greater than 0.05, and therefore we should not reject, but the power for acceptance of stationarity is probably low for this test. The result for the 0.8 cps peak is also marginal. We reject stationary recognizing that the probability of error is close to 0.05 if the statistics and processes underlying the .8 cps peak are indeed stationary. In the case of the high-frequency peak at 1.5 cps and 2.0 cps respectively we can decisively reject the hypothesis that the random variates underlying the observed sample variances are from the same normal population. The high-frequency noise above 1 cps appears to be very non-stationary when viewed over a 12 hour time span. There is no obvious diurnal trend in the observed spectral power of the high-frequency

peaks.

The character of the noise as seen on Figures 1 through 4 shows a high degree of symmetry, indicating that energy conversions resulting in more up-going or down-going energy are not "observed" to play an important role in the ambient noise. There is no obvious indication of reflected P-pulses although such noise may be obscured by the array response.

#### REFERENCES

Kullback, S., Information Theory and Statistics, Wiley, 1959,  
p. 319.

TABLE 1

<u>Frequency</u>	<u>Time</u>	3/20/ 00.3Z	4/42/ 00.0Z	6/20/ 00.0Z	9/00/ 00.0Z	11/20/ 00.0Z	14/00/ 00.0Z	15/15/ 00.0Z	Mean
.2 cps	1.35	1.02	1.14	0.79	1.05	0.64	1.02	1.00	
.8 cps	0.04	0.10	0.06	0.03	0.05	0.03	0.06	0.06	
1.5 cps	0.006	0.010	0.037	0.001	0.007	0.002	0.035	0.014	
2.0 cps	0.011	0.003	0.002	0.005	0.010	0.034	0.002	0.017	

TABLE 2

<u>Frequency</u>	<u>Mean Power</u>	<u>Range of Power</u>	<u>t</u>	<u>Hypothesis of Homogeneity</u>
.2 cps	1.00	0.64-1.35	9.7	Accepted
.8 cps	0.06	0.03-0.10	12.9	?
1.5 cps	0.014	0.001-0.037	91	Rejected
2.0 cps	0.017	0.002-0.055	98	Rejected

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 3/20/0 Z  
 SOFTWARE NO. = 11070      NO. OF CHANNEL = 8  
 SAMPLING RATE = 00.00      SAMPLING POINT = 1      TOTAL POINTS = 4000  
 THE NUMBER OF SMOOTHING TIME = 3

CHANNEL ID	SCALE FACTOR	DEPTH	U	V	W	SYMBOL
DW1	1.00	0.710	0	0	0	•
DW3	1.00	0.110	10	-10	0	•
DW4	1.00	1.000	10	-21	0	•
DW5	1.00	1.400	04	-07	0	•
DW6	1.00	1.13				

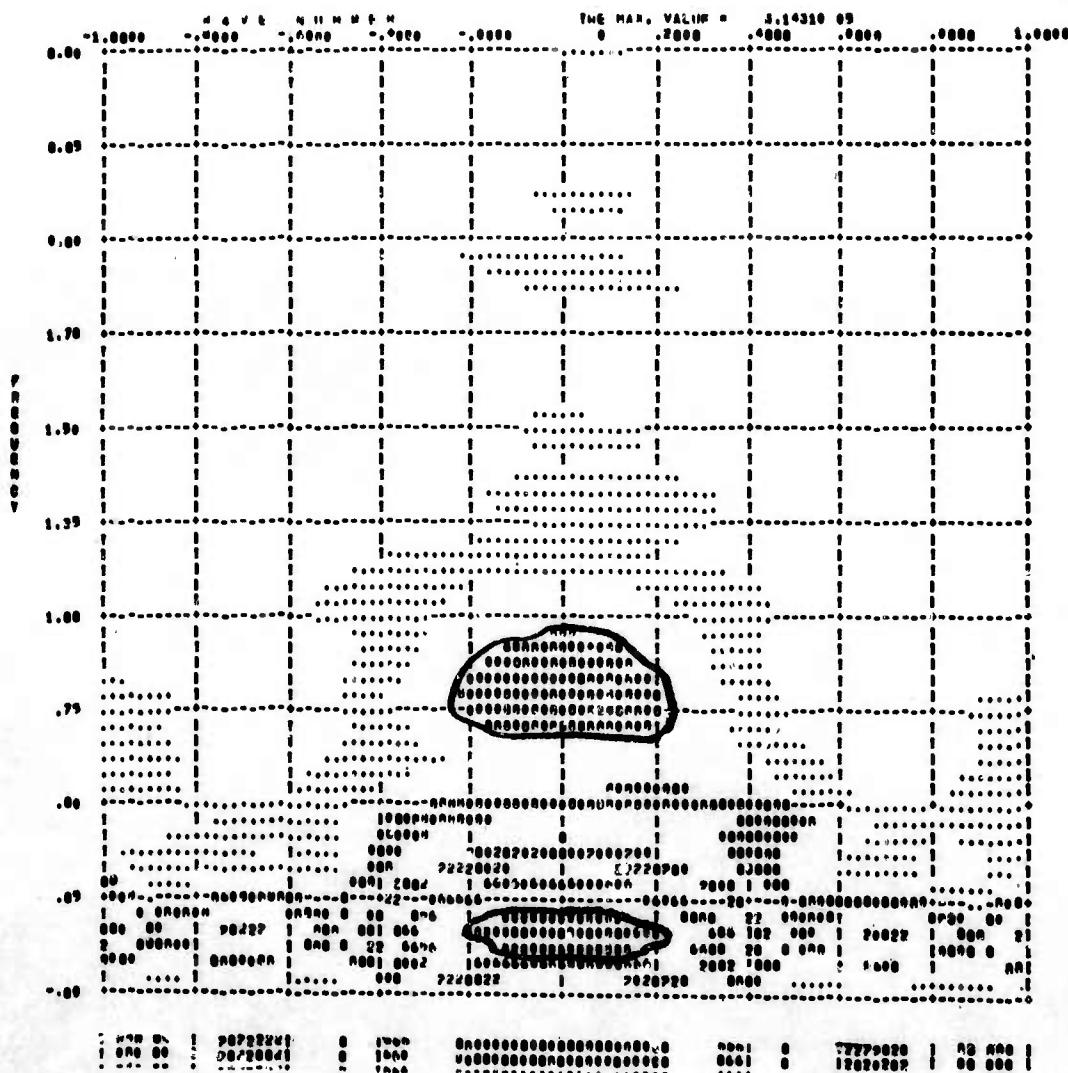
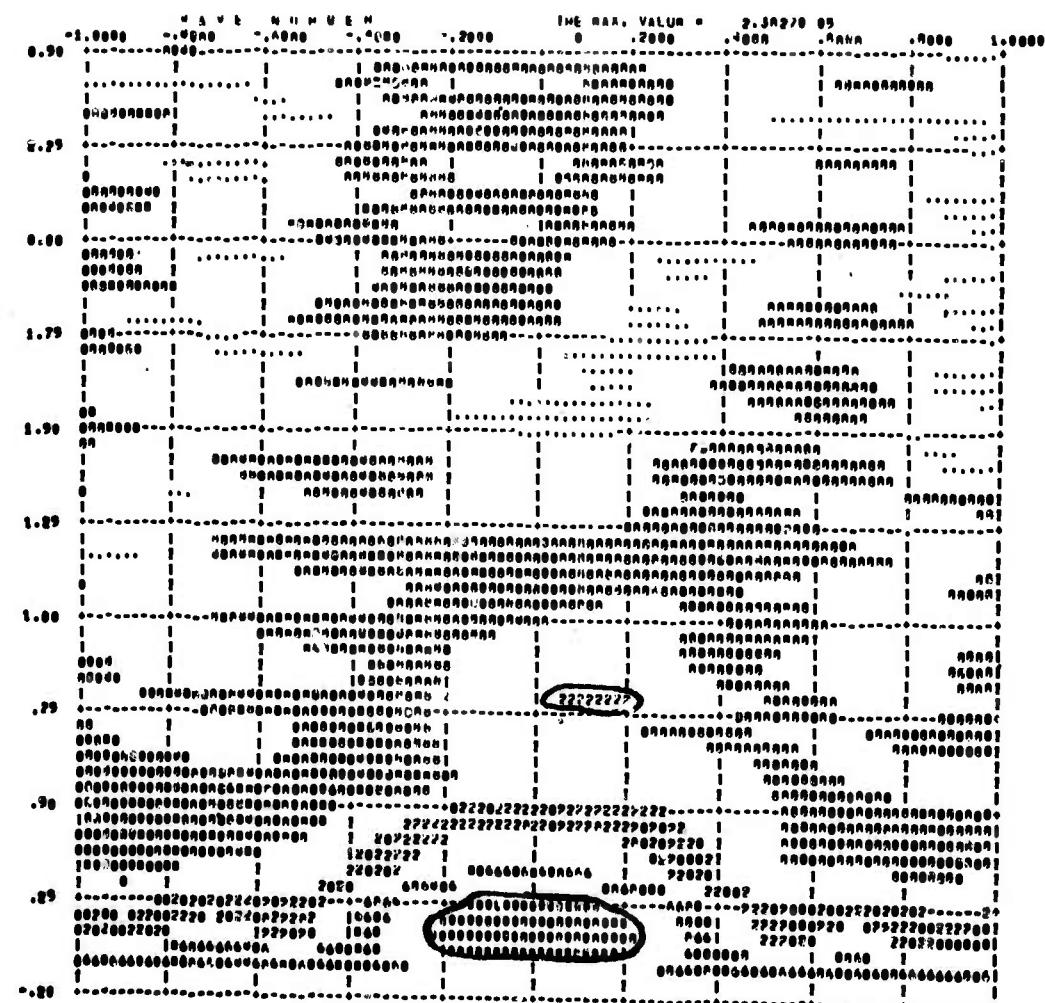


Figure 1. Unfiltered Noise

VFKSPTRM AMBIENT NOISE, URO, STARTING AT 4/42/00.0 Z

BRIGHAMAN NO. 8 11608 NO. OF CHANNEL 8 9  
DARLING FISH 20.00 STARLING POINT 1 TOTAL POINTS 4000  
THE BRIGHAM UP SMOOTHING LINE 8

CHANGER ID	SCALE FACTOR	DISTANCE	DO	SYMBOL
BW1	1.00	2.710	0 - 3	0
BW3	1.00	2.110	6 - 9	6
BW4	1.00	1.880	12 - 17	0
BW5	1.00	1.490	18 - 21	0
BW6	1.00	1.130	24 - 27	0



**Figure 2.** Unfiltered Noise

VFKSPTRM AMBIENT NOISE, UNF, STARTING AT 6/20/0,0 2

RECORDER NO. N 11681 NO. OF CHANNEL = 9  
 SAMPLING RATE = 20.000 STARTING POINT = 1 TOTAL POINTS = 4896  
 TWO NUMBER OF SMOOTHING TIME = 5

CHANNEL ID	SCALE FACTOR	DEPTH	U N	SYMBOL
DW1	1.00	2.710	0 - 3	0
DW3	1.00	2.110	0 - 9	0
DW4	1.00	1.900	12 - 19	2
DW5	1.00	1.490	10 - 21	0
DW6	1.00	1.130	24 - 27	0

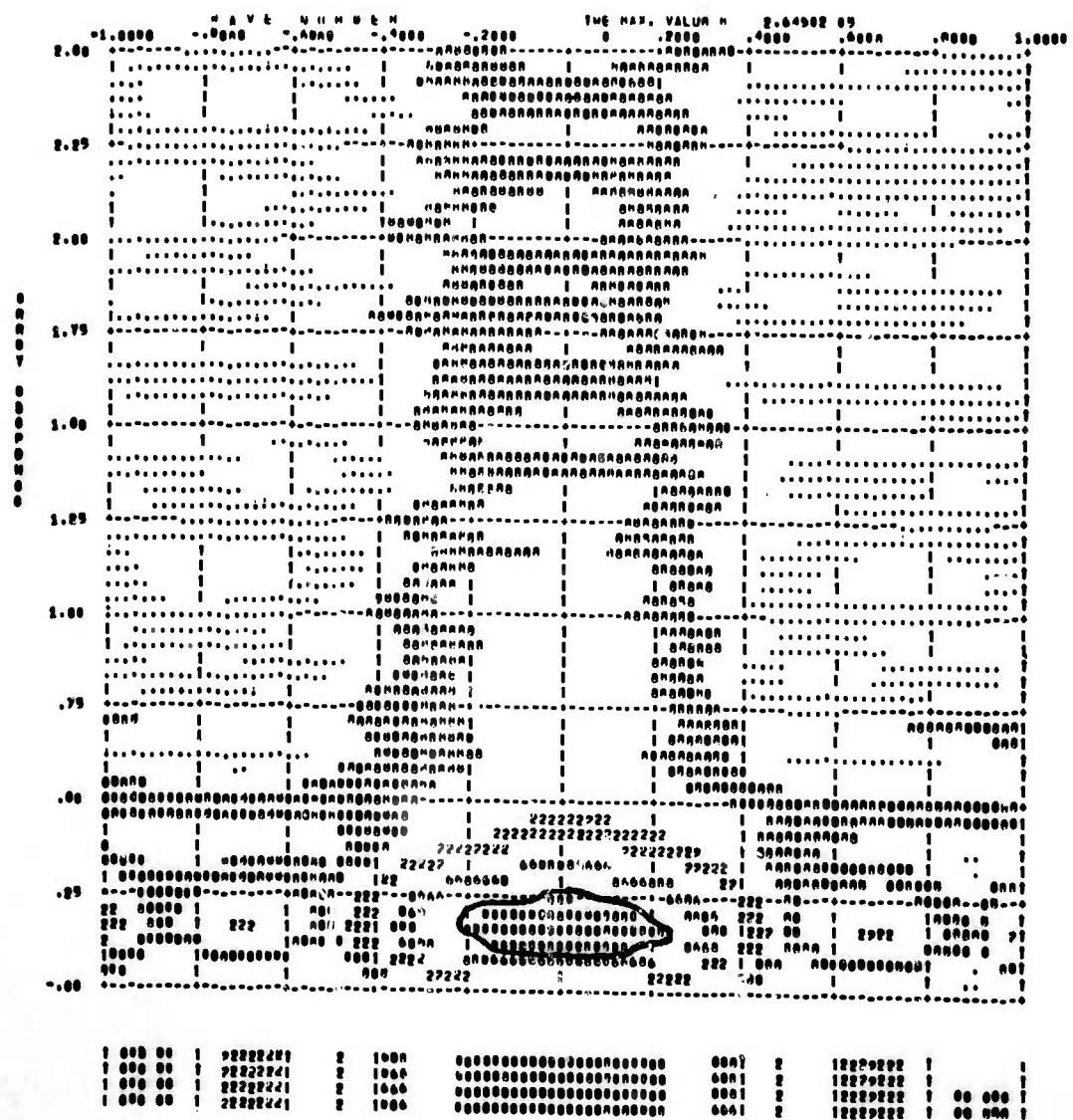


Figure 3. Unfiltered Noise

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 0/00/00.0 Z

DATA NUMBER NO. = 11802      NO. OF CHANNEL = 5  
 SAMPLING RATE = 00.00      STARTING POINT = 1      TOTAL POINTS = 4800  
 THE NUMBER OF COMPUTING TIME = 3

CHANNEL ID	SCALE FACTOR	DEPTH	U.R.	SYMBOL
UH1	1.00	2.710		
UH3	1.00	2.110	0 - 3	0
UH4	1.00	1.000	0 - 0	0
UH5	1.00	1.490	16 - 19	2
UH6	1.00	1.830	19 - 21	0
			24 - 27	0

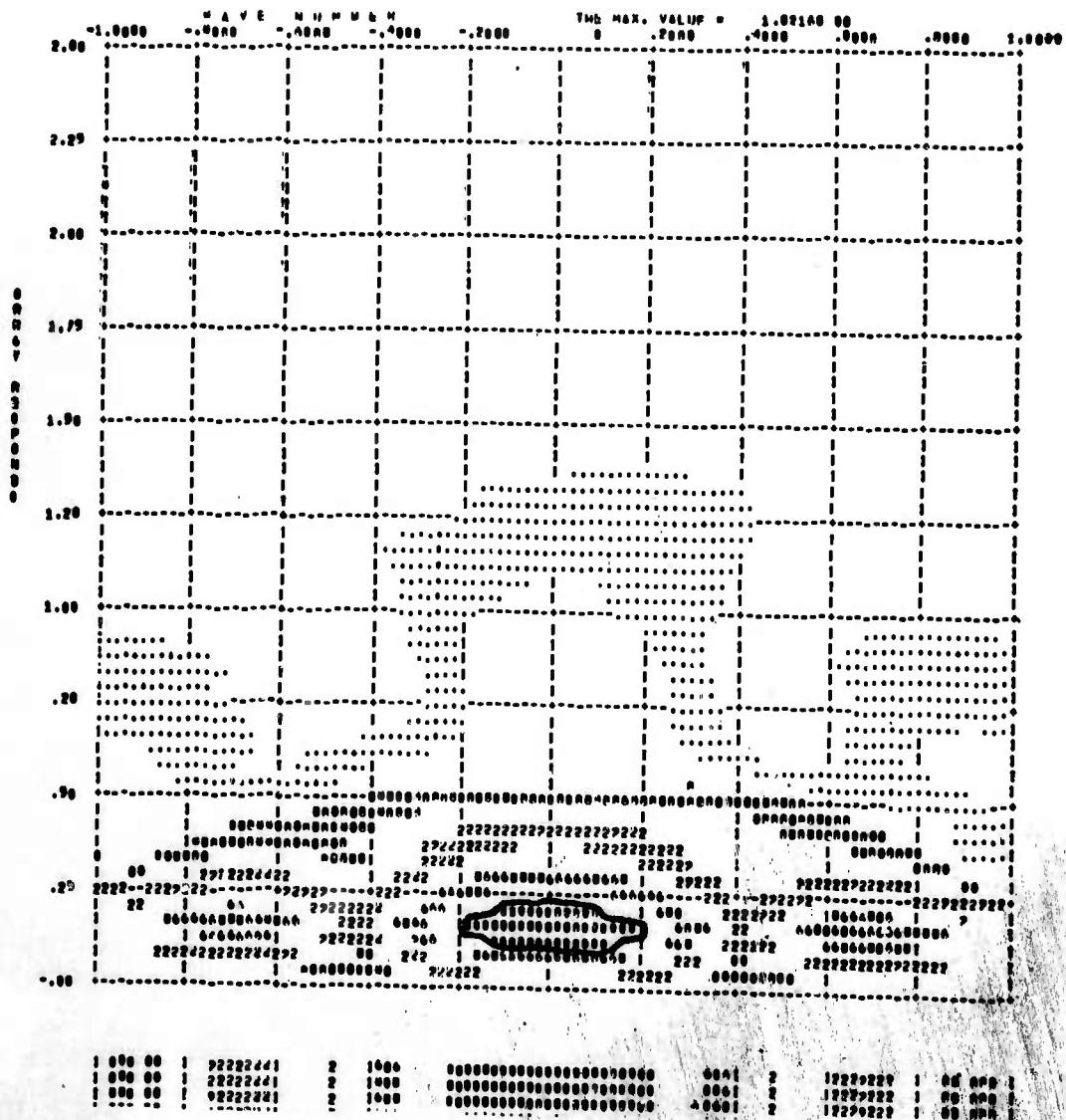


Figure 4. Unfiltered Noise

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 11/20/00.0 Z

DETECTOR NO. = 11003 NO. OF CHANNEL = 9

SAMPLING RATE = 2K.00 STARTING POINT = 1 TOTAL POINTS = 4096

INC NUMBER OF DUMPING TIME = 5

CHANNEL ID	SCALE FACTOR	DEPTH	U R	SYMBOL
0W1	1.00	2.710	0 - 3	0
0W3	1.00	2.110	4 - 7	0
0W4	1.00	1.670	12 - 15	0
0W5	1.00	1.490	16 - 21	0
0W6	1.00	1.130	24 - 27	0

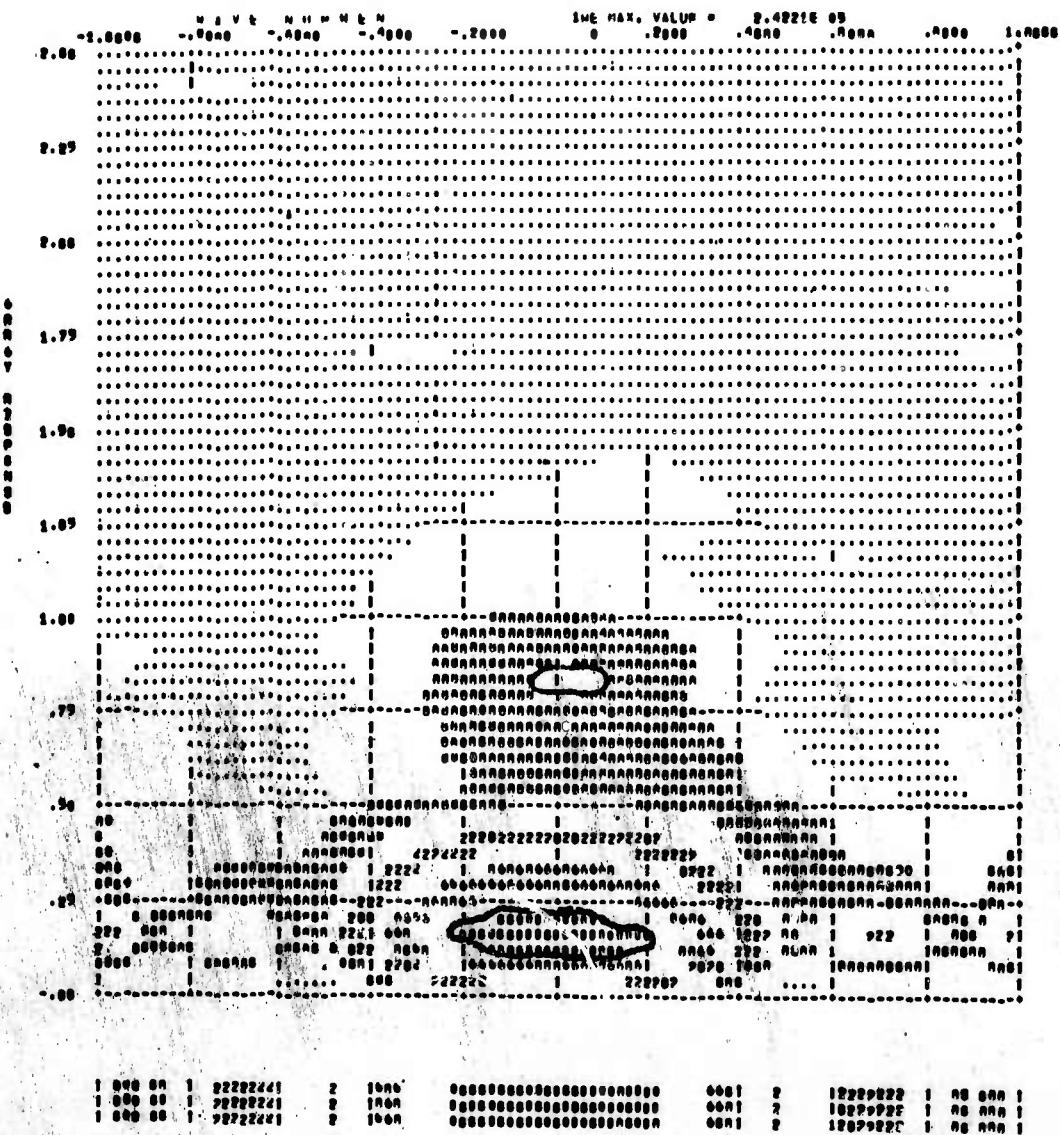


Figure 5. Unfiltered Noise

VFKSPTRM AMBIENT NOISE. UBO, STARTING AT 14/00/00.0 Z  
 SEISMICGRAM NO. = 11484 NO. OF CHANNEL = 8  
 SAMPLING RATE = 20.00 STARTING POINT = 1 TOTAL POINTS = 4896  
 THE LENGTH OF SMOOTHING TIME = 2

CHANNEL ID	SCALE FACTOR	DEPTH	SYMBOL
DH1	1.00	2.710	0 0
DH3	1.00	2.110	0 - 3
DH4	1.00	1.000	0 - 9
DH5	1.00	1.490	12 - 19
DH6	1.00	1.130	10 - 21
			24 - 27

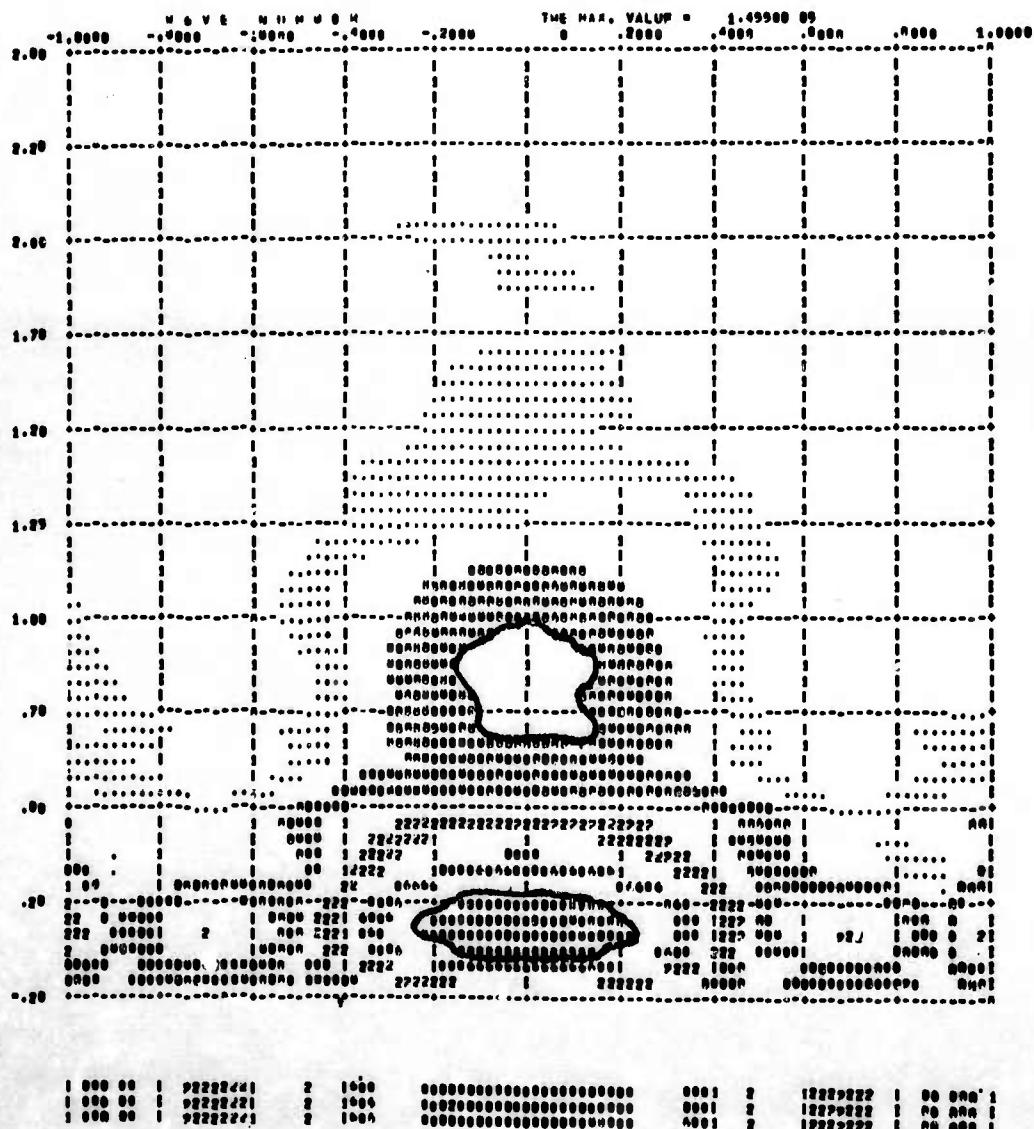
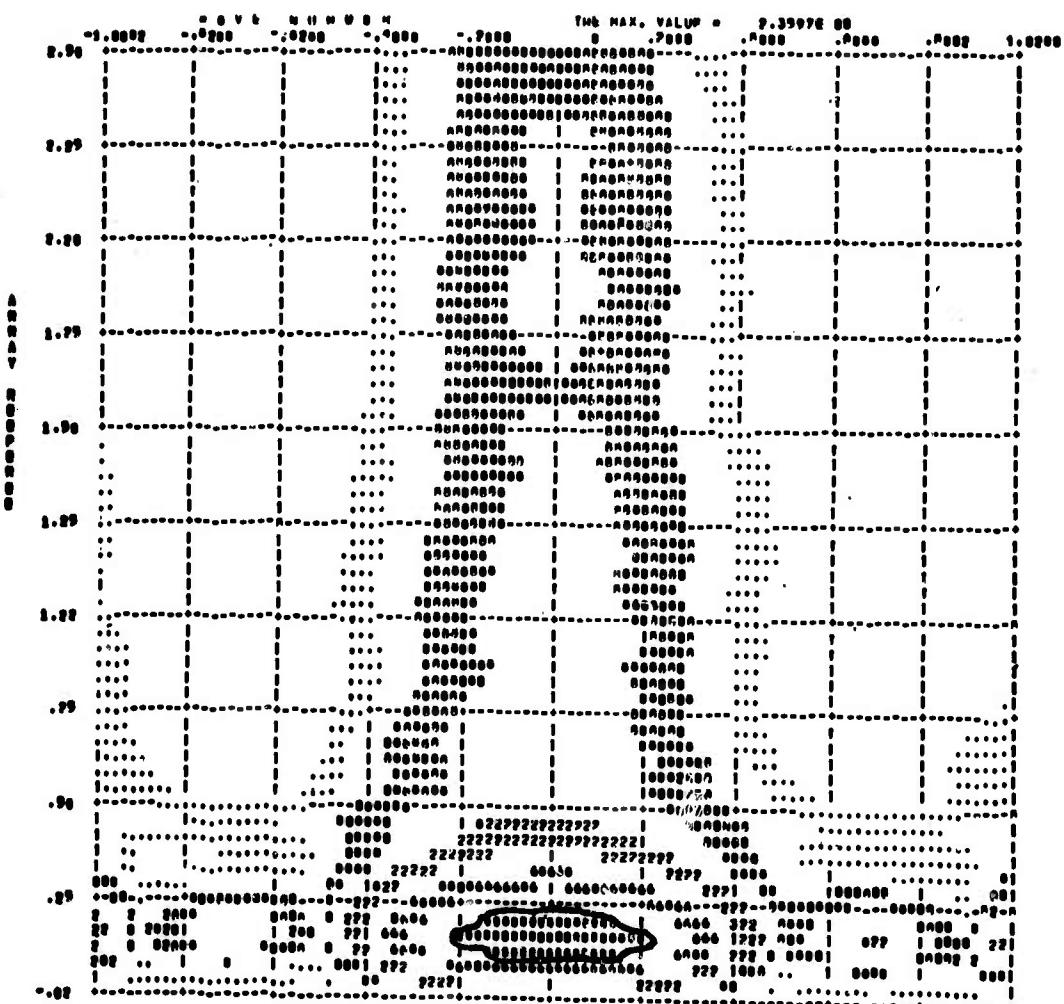


Figure 6. Unfiltered Noise

VFKSPTRM AMBIENT NOISE, UDO, STARTING AT 15/15/00.0 Z  
SAMPLING HZ = 11648 NO. OF CHANNEL = 5  
SAMPLING TIME = 20.00 STARTING POINT = 1 TOTAL POINTS = 4896  
THE NUMBER UP SMOOTHING TIME = 5

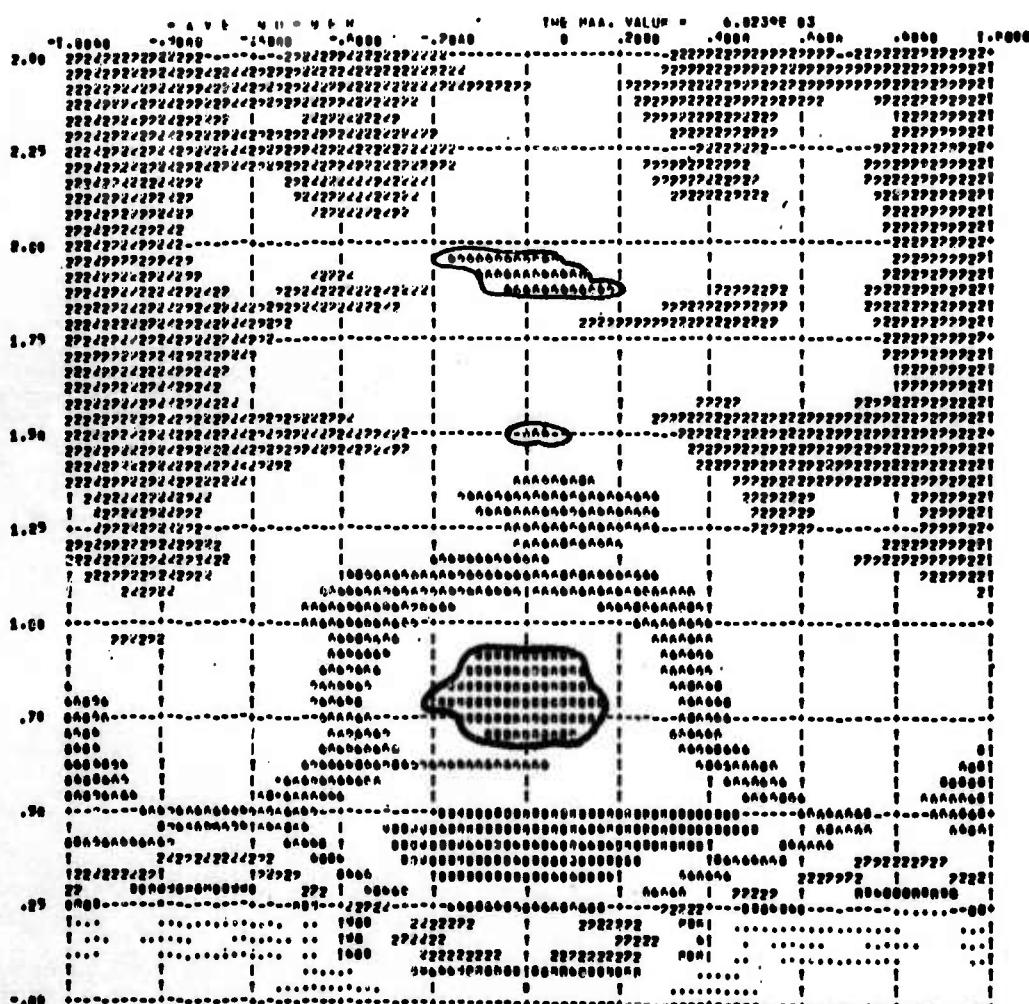
CHANNEL ID	SCALE FACTOR	DEPTH		SIGNAL
BW1	1.00	2.710	0 0	
BW3	1.00	2.110	0 - 3	0
BW4	1.00	1.000	6 - 9	0
BW6	1.00	1.470	12 - 17	?
BW8	1.00	1.130	18 - 01	0
			24 - 27	



**Figure 7. Unfiltered Noise**

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 3/20/00.0 Z

WATERFALL NO.	SCALE FACTOR	DEPTH	V.P.	SYMBOL
W.W.1	1.00	2.710	8 - 3	0
W.W.3	1.00	2.110	6 - 7	0
W.W.4	1.00	1.480	12 - 19	2
W.W.5	1.00	1.090	16 - 21	0
W.W.6	1.00	1.130	24 - ??	0

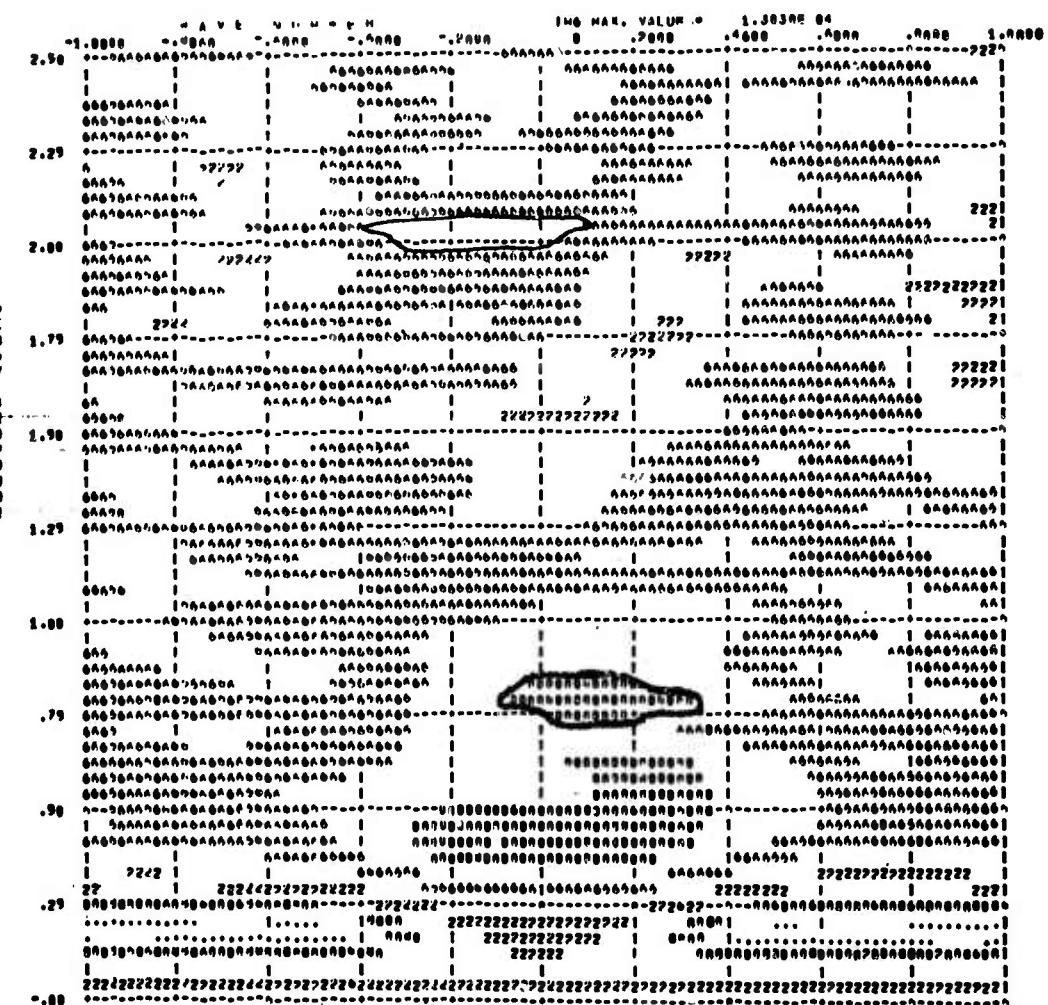


**Figure 8. Filtered Noise Band: (.3 < f < 3 cps)  
Rolloff: .1 cps**

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 4/42/00.0 Z

NO. OF CHANNELS = 2  
NO. OF CHANNELS = 2  
TOTAL POINTS = 3000

CHANNEL ID	SALT FACTOR	DEPTH	D D	SYMBOL
UH1	1.00	2.710	0 - 3	A
UH3	1.00	4.110	0 - 4	B
UH4	1.00	1.800	12 - 15	Z
UH5	1.00	1.400	10 - 21	A
			24 - 27	C

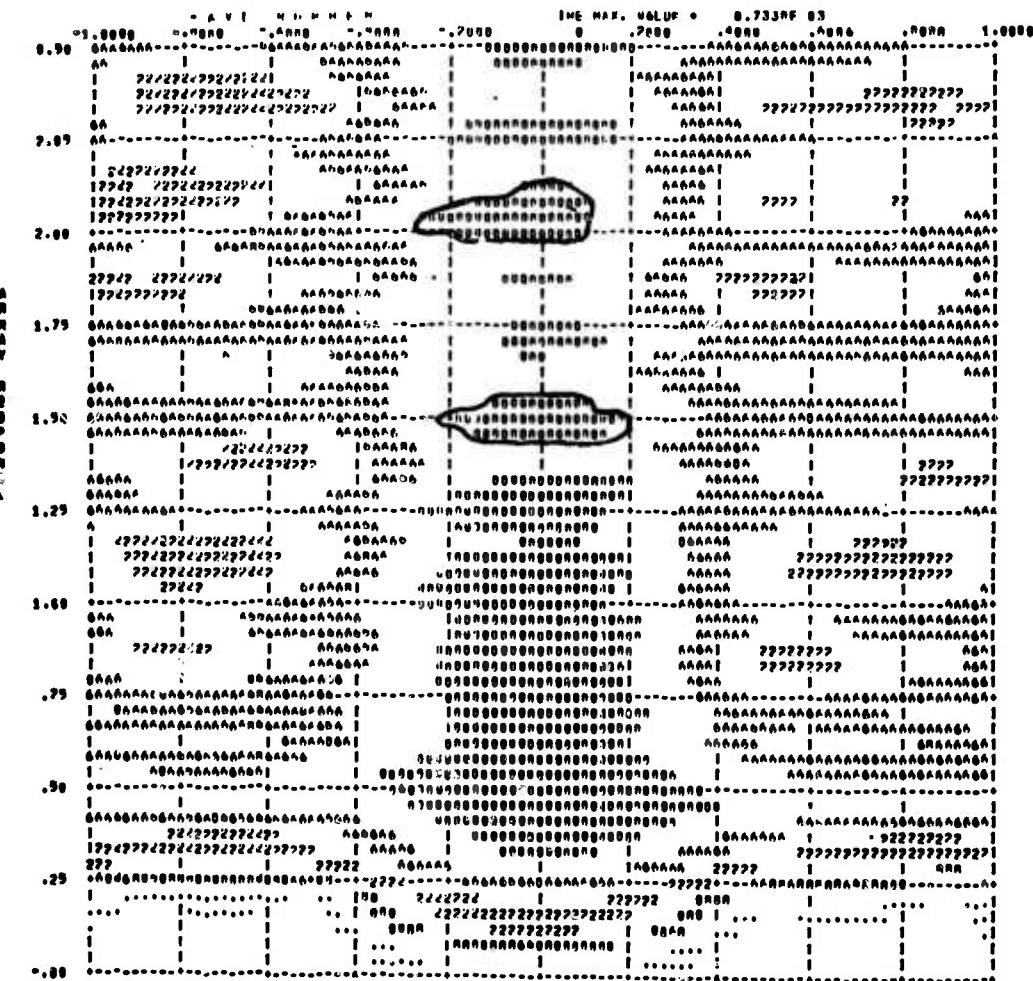


**Figure 9. Filtered Noise Band: (.3 < f < 3 cps)  
Rolloff: .1 cps**

VFKSPTRM AMBIENT NOISE, UNR, STARTING AT 6/20/00, 0 Z

S. ISHIGAKI NO. 6 ISLET  
NO. OF CHANNEL = 5  
SAMPLED RATE = 40000 STARTING POINT = 1 TOTAL POINTS = 40000  
THE NUMBER OF SMOOTHING TIME = 2

CHANNEL ID	SCALE FACTOR	DEPTH	P	SYMBOL
UM1	1.00	2.710	0 - 3	0
UM3	1.00	2.110	6 - 9	A
UM4	1.00	1.880	12 - 15	?
UM5	1.00	1.690	18 - 21	0
UM6	1.00	1.410	24 - 27	-

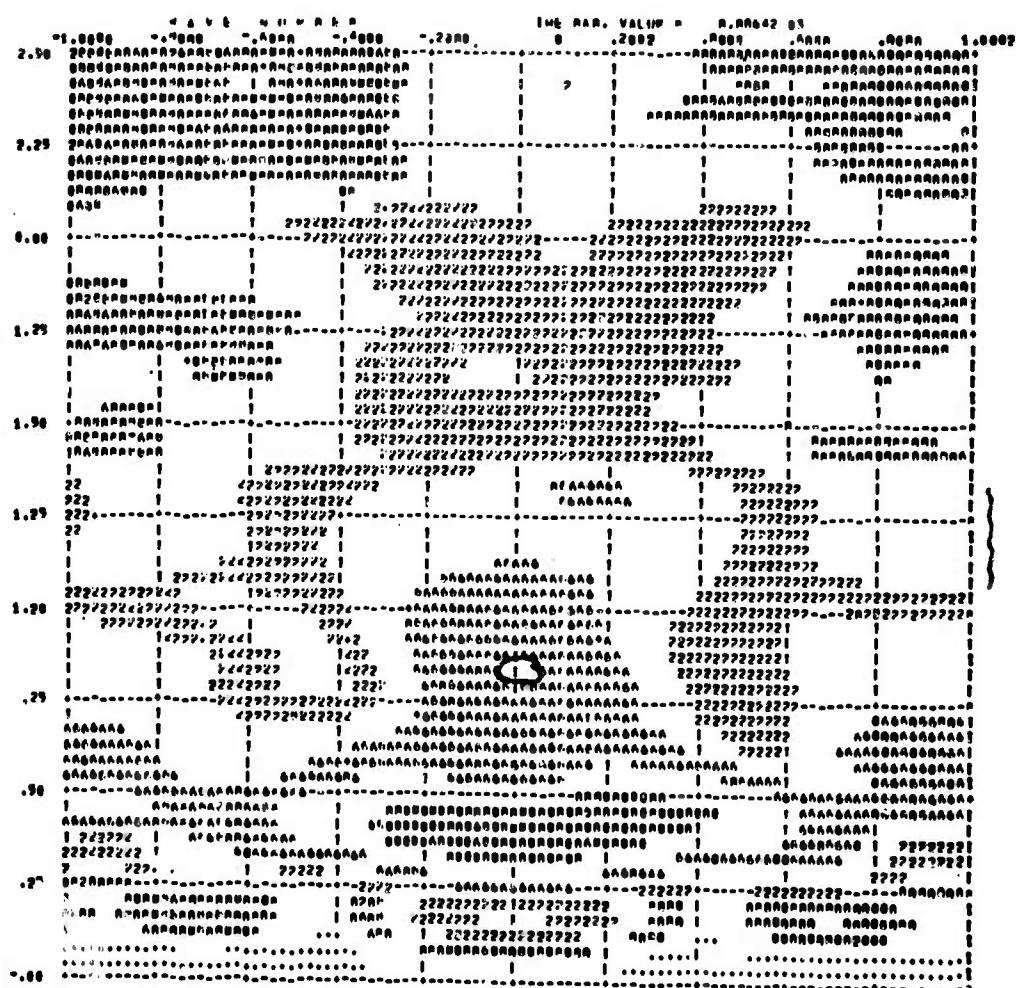


0.00	00	22222222	2	0000	0000000000000000	0001	2	12222222	1	00000
0.00	00	22222222	2	0000	0000000000000000	0001	2	12222222	1	00000
0.00	00	22222222	2	0000	0000000000000000	0001	2	12222222	1	00000

Figure 10. Filtered Noise Band: (.3<f<3cps)  
Rolloff: .1cps

WFKSPTM AMBIENT NOISE. UDO. STARTING AT 9/00/00.0 Z

CHANNEL ID	SCALE FACTOR	REFIN	U V	SYMBOL
0w1	1.00	2.710	0 - 3	0
0w3	1.00	2.110	0 - 5	0
0w4	1.00	1.000	12 - 15	0
0w5	1.00	1.480	10 - 21	0
0w6	1.00	1.130	20 - 27	0



**Figure 11. Filtered Noise Band: (.3 < f < 3 cps)  
Rolloff: .1 cps**

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 11/20/00.0 Z  
 DEPTH IN FT = 11400 NO. OF CHANNEL = 9  
 SAMPLING RATE = 240000 STARTING POINT = 1 TOTAL POINTS = 4800  
 THE NUMBER OF BURNING TIME = 7

CHANNEL ID	SCALE FACTOR	DEPTH	SYMBOL
UH1	1.00	2.710	0 - 0
UH2	1.00	2.110	0 - 3
UH3	1.00	1.600	0 - 7
UH4	1.00	1.490	12 - 15
UH5	1.00	1.330	10 - 21
UH6	1.00		24 - 47

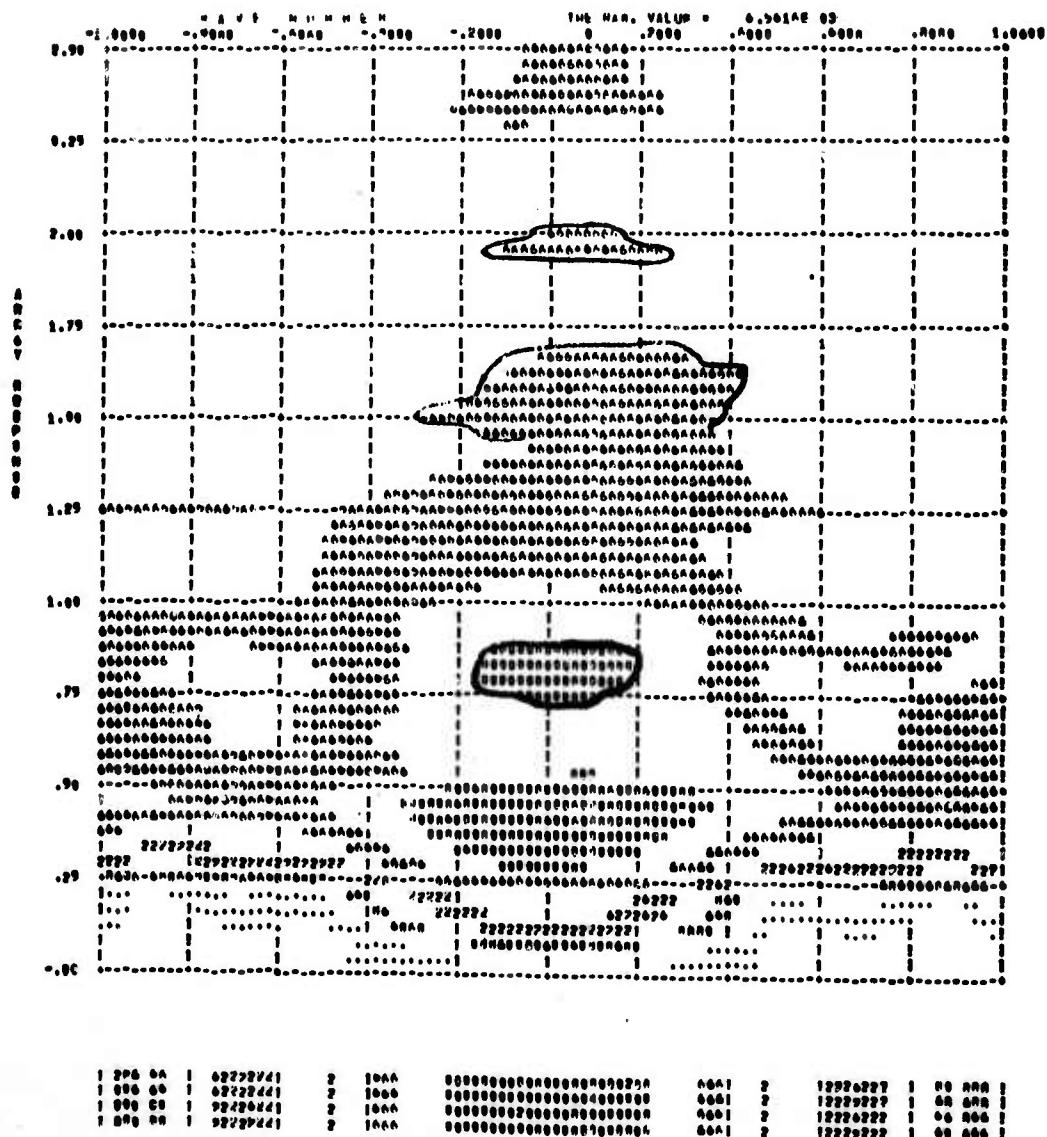
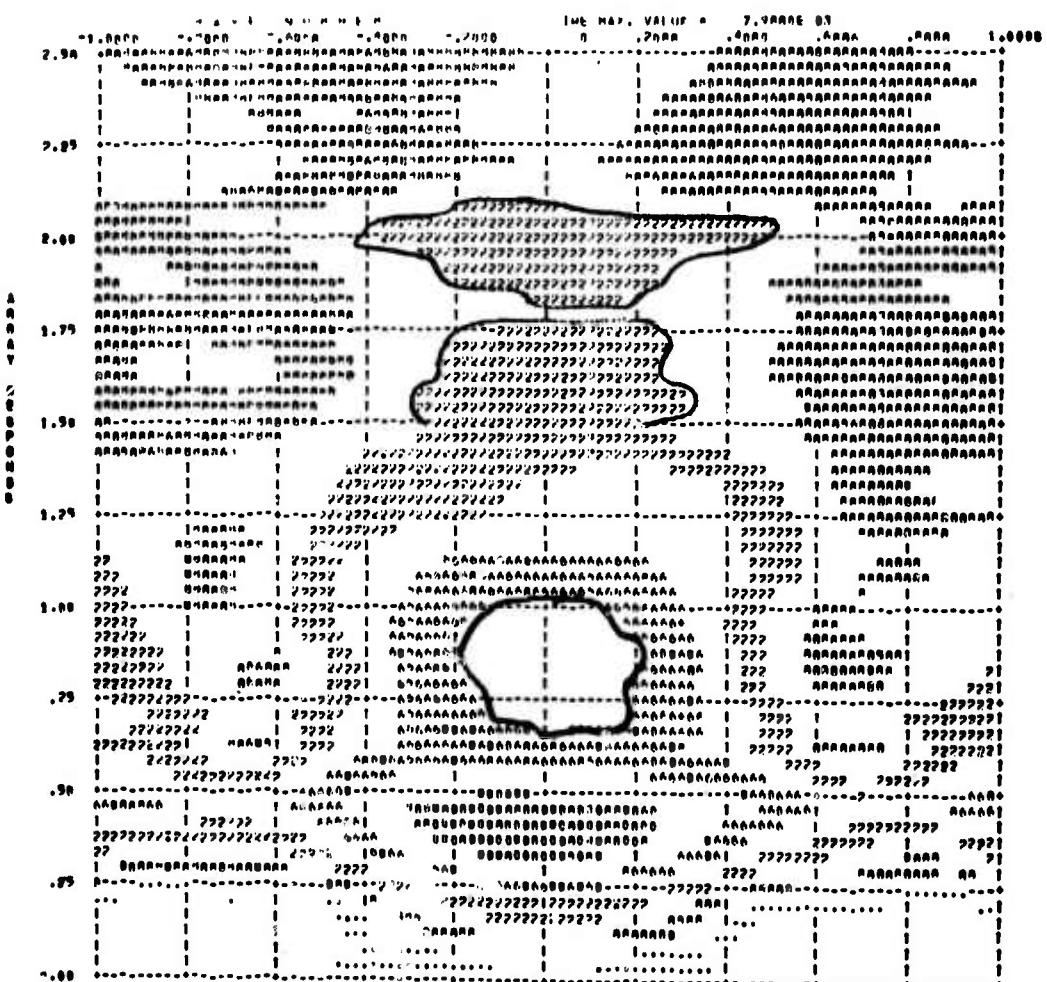


Figure 12. Filtered Noise Band: (.3<f<3cps)  
 Rolloff: .1cps

MENSP103 AMBIENT NOISE, 0.000, STARTING AT 14/00/00,0 Z

QUANTITY	STATE FACTOR	DEPTH	PERCENT	SYMBOL
BOT	1.00	2,710	0 - 3	0
BOT	1.00	2,110	6 - 9	0
BOT	1.00	1,890	12 - 19	0
BOT	1.00	1,690	16 - 21	0
BOT	1.00	1,130	28 - 47	0



**Figure 13. Filtered Noise Band: (.3 < f < 3 cps)**  
**Rolloff: .1 cps**

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 15/15/00.0 Z

DEFINITION NO. = 10005	NO. OF CHANNEL = 6
RECORDING RATE = 4000	STARTING POINT = 1
TOTAL RECORDS = 4000	
THE NUMBER OF BREATHING TIME = 5	

CHANNEL ID	SCALE FACTOR	DECODE		SYMBOL
UM1	1.00	2.710	0.6	
UM3	1.00	2.710	8 - 3	
UM4	1.00	1.000	6 - 9	
UM5	1.00	1.470	12 - 15	
UM6	1.00	1.130	10 - 21	
			24 - 27	

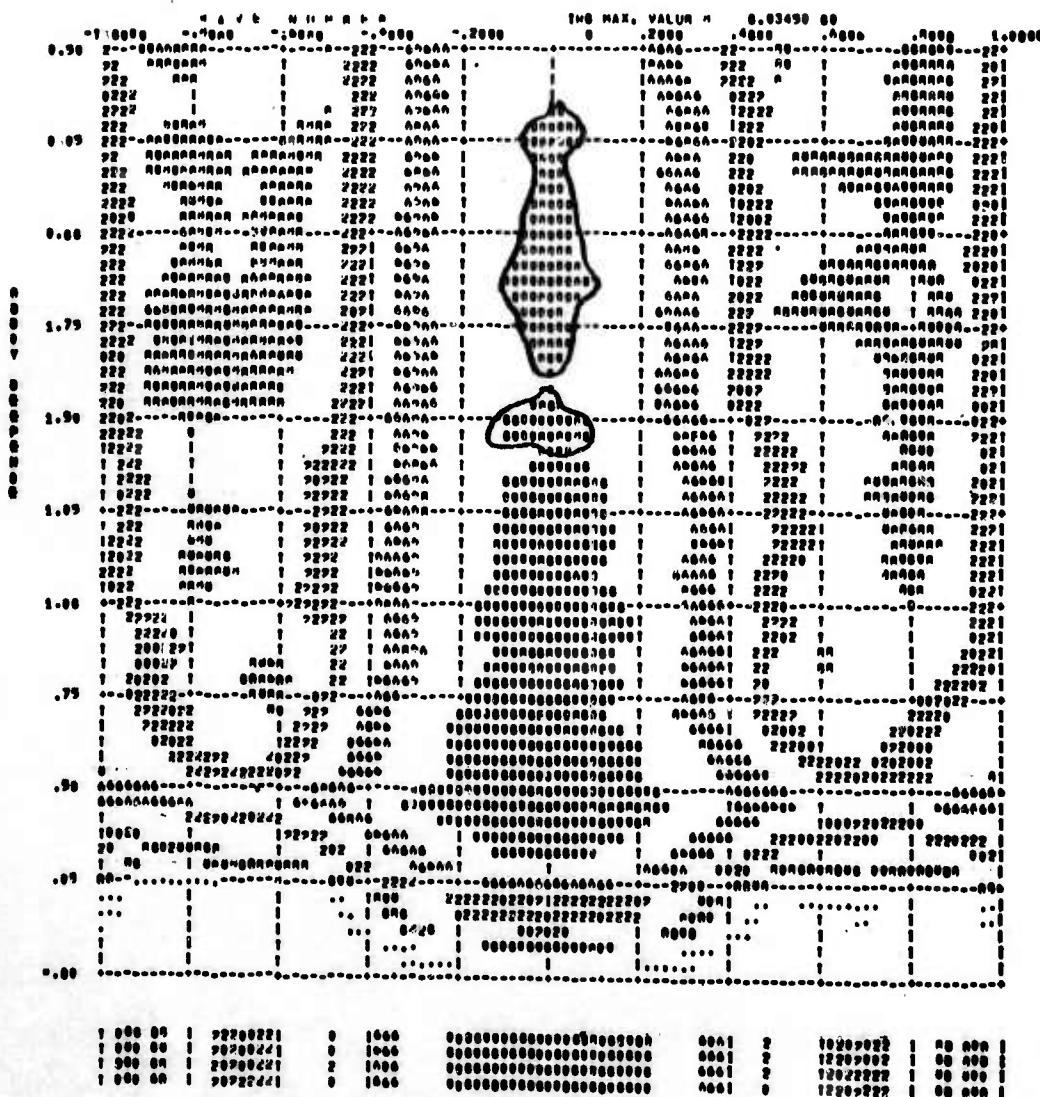


Figure 14. Filtered Noise Band: (.3<f<3cps)  
Rolloff: .1cps

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Security Classification

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1. ORIGINATING ACTIVITY (Corporate author) TELEDYNE, INC. ALEXANDRIA, VIRGINIA		2a. REPORT SECURITY CLASSIFICATION Unclassified
		2b. GROUP ---
3. REPORT TITLE STABILITY OF FREQUENCY-WAVENUMBER NOISE SPECTRA AT UBO		
4. DESCRIPTIVE NOTES (Type of report and inclusive date) Scientific		
5. AUTHOR(S) (Last name, first name, initial) Sax, Robert L.		
6. REPORT DATE September 8, 1967	7a. TOTAL NO. OF PAGES 24	7b. NO. OF REPS 1
8a. CONTRACT OR GRANT NO. F 33657-67-C-1313	8b. ORIGINATOR'S REPORT NUMBER(S) 197	
8c. PROJECT NO. VELA T/6702	8d. OTHER REPORT NO(S). (Any other numbers that may be assigned to this report) ---	
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11. SUPPLEMENTARY NOTES ----	12. SPONSORING MILITARY ACTIVITY ADVANCED RESEARCH PROJECTS AGENCY NUCLEAR TEST DETECTION OFFICE WASHINGTON, D. C.	
13. ABSTRACT Seven four-minute samples of the ambient noise were subjected to frequency-wavenumber (F-K) spectral analysis. In order to observe the range and character of variations in the F-K power spectrum. The observations are derived from the same normal population. The apparent variation in the underlying noise statistics or processes do not suggest gradual diurnal variations in the noise power, but large and apparently random interday fluctuations.		

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